Lighting accounts for 25% of the electricity used in the Federal sector. If new lighting technologies were used everywhere in the Federal sector, electricity required for lighting would be cut by 50%, electrical demand reduced, and working environments improved. Although every application must be judged separately, some lighting retrofits are generally applicable, especially for aging lighting systems. For example, most existing fluorescent lighting systems can be cost-effectively upgraded to T-8 lamps and electronic ballasts. Compact fluorescent lights (CFLs) are available in a wide range of sizes and wattages, making them good replacements for incandescent lamps, especially where burning hours are long (>4000 hours/year). Mercury vapor lamps can be replaced with metal halide lamps that are much more efficient. If lighting is left on wastefully in unoccupied spaces, occupancy sensors, which detect the presence (or absence) of people, can effectively eliminate waste.

Action Moment

Consider retrofitting the lighting system whenever undertaking any renovations or new additions. As the usage in a facility changes, the old lighting system may be inappropriate and consume more energy than necessary for the new tasks being performed. Adding partitions or changing workspace locations may reduce a lighting system's effectiveness, thus presenting a good time to upgrade the ceiling lighting system and add task lighting where appropriate. Always consider the effect of lighting loads when replacing HVAC systems. By upgrading the lighting system and reducing lighting loads at the same time the HVAC system is changed, it may be possible to specify a smaller HVAC system, resulting in first cost capital savings.

Lighting Technical Issues

FEMP's Federal Relighting Initiative is a program that provides facility managers with lighting evaluation tools and lighting retrofit information. Relighting a building can dramatically reduce the amount of energy used for lighting, improve the working environment, and reduce lighting maintenance costs. Lighting power densities of 2.5 watts per square foot (typical for many office buildings) can be reduced to 1 watt per square foot in new buildings and major renovation by: (1) installing modern, efficient luminaires; (2) replacing ballasts and lamps with modern components; (3) implementing task/ambient lighting; and, (4) installing lighting controls. The lower lighting power densities that can result from sensitive design and refurbishment can surpass ASHRAE 90.1 guidelines.

1 **Lighting Technology Screening Matrix (LTSM)** software evaluates different lighting technologies on per-fixture basis. The algorithms are based on lumen equivalents, but the user can adjust for areas that are overlit or underlit. The LTSM program is primarily a financial tool that generates a list of potential cost-effective lighting retrofits.

2 **Lighting Systems Screening Tool (LSST)** software allows managers to evaluate system retrofits on a facility-wide basis. It can either make assumptions about existing lighting for a first cut, or allow more precise evaluation using actual data entered for the facility.

3 **The Federal Lighting Expert (FLEX)** is an expert system that can assist facility managers in optimizing lighting retrofit projects. It is user-friendly, can be used by non-experts, and has a product database with performance specifications and cost information.

4 **The Master Specifications (Version 2.03)** is a generic specification for energy-efficient lighting systems targeted at Federal Facilities. It addresses lamp, ballasts, reflectors and luminaires. Parts of the specification can be "lifted" verbatim to assist in the preparation of technical specifications for specific projects.

Lighting design that provides visual comfort at low energy costs is more of an art than generally thought. If you lack the in-house expertise, it makes good economic sense to contact a specialized lighting consultant to get some sound expert advice before embarking on an expensive lighting retrofit project. To use the consultant's time most effectively, first consider these key factors:

- Is the lighting system older than 15 to 20 years?
- Have the visual tasks changed (i.e., greater use of computers)?
- Are there complaints about the existing system?

If all the above are true, then consider replacing the existing fixtures rather than simply upgrading the ballasts and lamps. On the other hand, if there is asbestos in the ceiling, it may be cost-prohibitive to replace the fixtures because the asbestos hazard would need to be abated as well. Under these circumstances, replacing the T-12 lamps with T-8 lamps, installing electronic ballasts, and (possibly) installing reflectors may be the best bet.

1 **Look at the task.** Consider whether current lighting needs are being met by the existing lighting system. Invest in an inexpensive light meter ($100 to $200) so you can measure existing light levels. Check the Illuminance Selection Tables in the IESNA Lighting Handbook to see if your existing light levels are appropriate to the expected tasks. Take into account the fact that light levels may go up after a lighting retrofit because of the new lamps and fixtures (see maintenance section below).

2 **Choose efficient fixtures**. If you elect to replace the existing fixtures, make sure you select fixtures that are efficient and have the appropriate light distribution for the expected tasks. For example, in areas with computers, consider replacing "prismatic lens" fixtures with efficient "parabolic" fixtures which minimize high angle light that can cause reflected glare in computer screens. The fixture efficiency, which quantifies the percentage of the lamp's light that exits the fixture, is nearly always available from the manufacturer. Forward-thinking lighting companies will also publish a luminaire efficacy rating (LER) for their major fluorescent fixture lines. LER includes the influence of the lamp and ballast and is therefore a superior method for comparing the overall energy efficiency performance of similar class luminaires than simple fixture efficiency.

3 **Use high coloring rendering lamps.** Modern, efficient fluorescent lamps use rare earth phosphors to provide good color rendition. The color rendition index (CRI) describes how a light source affects the appearance of a standardized set of colored patches. The CRIs of lamps can only be compared if the lamps are approximately the same color temperature (see below). A lamp with a CRI of 100 will not distort the appearance of the patches compared to a reference lamp. A lamp with a CRI of 50 will significantly distort colors (to the same extent as a Warm White fluorescent lamp). T-8, T-l0, and compact fluorescent lamps all have CRIs greater than 70; some are as high as 90. The minimum acceptable CRI for most applications is 70 (except for special cases, such as signage). Fluorescent lamps with CRIs over 80 are available but at a premium.

4 **Consider color temperature.** This measures the color of the lamp itself and is expressed in the Kelvin temperature scale. Color temperatures are: 2,700K for "warm"; 3,500K for balanced color applications; and 4,100K for "cool" bluer applications.

References

Department of Energy, *Advanced Lighting Guidelines: 1993*, Washington DC, Report Number: DOE/EE—0008, NTIS Order Number DE94005264. Provides acceptable lighting levels for various applications.

American Society of Heating, Refrigerating, and Air Conditioning Engineers, *ASHRAE Standard 90.1*

Illuminating Engineering Society of North America, *IES Lighting Handbook*, New York, NY, (212) 248-5000 or http://www.ies.org.

Contacts

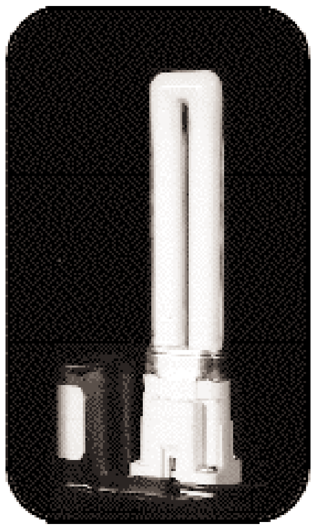
The FEMP Help Desk at (800) DOE-EREC has information about the Relighting Initiative, training courses devoted to lighting technologies and techniques, and software.

"ProjectKalc" software is available from the EPA Green Lights Hotline at (202) 775-6650.

Compact Fluorescent Lighting 3.4.1

Compact fluorescent lamps (CFLs) are energy-efficient, long-lasting substitutes for incandescent lamps. Introduced in the early 1980s, these lamps use about one-half to one-tenth the energy to produce the same light output, and last up to thirteen times longer than the incandescent lamps they replace, providing an attractive return on investment.

Action Moment



Compact fluorescent lamps should be substituted for incandescent lamps, especially where burn hours are more than one hour per day. Substitution is best done by re-fixturing or re-socketing rather than by screw-in adapters. This will help to ensure that incandescent lamps are not later substituted when the CFL fails.

Technical Information

1 **Compact fluorescent lamps** have excellent color rendition and are available with a wide variety of sizes, shapes, and wattages. They are suitable both in new buildings and in renovations.

As a rule of thumb, 1 watt of compact fluorescent can replace 3 to 4 watts of incandescent lighting. For example, replace a 60 watt incandescent lamp with 15 to 20 watts of compact fluorescent. If the fixture efficiency can also be improved during retrofitting (for example by replacing a bare incandescent lamp in a recessed can fixture with a reflectorized screw-in CFL) up to 5 watts of incandescent can be replaced by 1 watt of fluorescent. But remember that the light output of fluorescent lamps is sensitive to both temperature and burning position while an incandescent bulb is not.

2 **Fixtures for compact fluorescent lamps** come in a variety of styles to meet many lighting situations. CFL fixtures contain ballasts required to operate the lamps and special sockets to retain the lamps in their proper position. Retrofit lamps are available that contain integral ballasts and screw-base sockets. See the caution on the next page regarding retrofit lamps.

3 **Lighting surveys** are the first step toward planning replacement of incandescent lamps with CFLs. Although not every incandescent lamp has a compact fluorescent equivalent, facility managers can establish a plan to gradually change over to these more cost-effective alternatives. The table below shows some good opportunities. Software such as the Lighting Technology Screening Matrix (LTSM) and the Lighting System Screening Tool (LSST) can help in the planning and the financial assessment. See section 3.4 for a description of these tools and how to obtain them.

End Use	Compact Fluorescent Application
Outdoor Safety Area	Use for walkways, stairways, and other relatively small areas above 32°F (unless low-temperature ballasts are used).
Outdoor Decorative	Compacts are excellent candidates for walkways, common areas, and landscaping, above 32˚F (unless low temperature ballasts are used).
Storage Areas	Compacts are a good choice for small storage areas used more than one hour per day, especially where tight beam control is not important.
Restrooms, Lobbies, Hallways	CFLs in downlights or wall-packs can replace incandencents used for general bathroom lighting. Good color rendition is advised near mirrors.

Lamp life of CFLs is up to 10,000 hours, five to thirteen times longer than incandescent lamps. Long life helps provide a favorable life-cycle cost and labor savings for lamp replacement.

Over-lighting is common, so direct one-for-one replacement of incandescent lamps with their CFL equivalent may result in ongoing over-lighted conditions. As part of a lighting survey, it is important to determine the lowest wattage lamp that can be used for the application.

Look for applications with long burn hours. Interior and exterior hallways and walkways provide excellent cost-effective replacements for incandescent fixtures, since these locations typically have long burn hours. Wall packs and sconces containing CFLs make excellent retrofit fixtures for these applications.

The National Electric Code forbids the use of incandescent fixtures in small clothes closets and other locations where the heat from incandescent lamps can be a fire hazard. CFLs can be used in many of these applications due to their low heat generation.

When replacing incandescent lamps in existing recessed cans with screw-in CFLs, it is often best to use a CFL with a built-in reflector or a retrofit CFL reflector fixture.

$ Replacing incandescent fixtures with compact fluorescent fixtures will typically achieve a 35% annual return on investment.

Replacing long-burning (greater than 4000 hours/year) incandescent fixtures with compact fluorescent lamp fixtures will pay back in under 3 years—a 35% return on investment. Although utility rebate money is drying up, many utilities still offer direct rebates for installing screw-in compact fluorescent lamps (expect $5/lamp rebate) or hardwire CFL units (expect a $15/lamp rebate).

Retrofit lamps that contain the lamp, ballast, and screw base all in one unit for easy retrofit are widely available. As a rule, however, these units should be avoided for several reasons: (1) they are often replaced by incandescent lamps when they fail; (2) often the geometry of the bulky retrofit makes it difficult to place the lamp in a good location in the fixture for proper light exit; (3) the ballasts should out-last lamps by a factor of five or more, and disposing of the ballast after each lamp life is wasteful; (4) depending on the manufacturer and configuration, the heat from the integral ballast cannot dissipate very well, and both lamp life and ballast life is short compared to the alternative of re-fixturing; and, (5) it is too easy for the relatively expensive retrofits to be stolen. It is much wiser to re-fixture or re-socket initially.

Some lamps take a second to turn on and flicker initially, and some do not. Consult your supplier about this issue.

Places to avoid using CFLs:

1 where there is a requirement for tight light beam control CFLs cannot focus their output as well as halogens and should be avoided.

2 in spaces with ceiling height over 20 feet. For high bay spaces, too many CFL fixtures would be required to achieve a satisfactory light level. Consider metal halide lamps instead. For medium bay spaces (12 to 20 foot ceilings) fixtures holding multiple high output CFLs may be appropriate, especially if used with occupancy sensors.

3 in areas where the temperature is likely to remain below 32^{o}F for extended periods of time, avoid CFLs or use low temperature ballasts.

4 in exit signs. Replace incandescent lamps with LED retrofits, which are an even more cost-effective alternative.

References

Western Area Power Administration, *Electric Utility Guide to Marketing Efficient Lighting*, (ref. contract DE-AC65-86WA00467), Golden, CO, 1990.

Contacts

Defense Logistics Agency, Defense Supply Center, Richmond, VA (800) DLA-BULB, or at http://www.dgsc.dla.mil

New technologies for 4-foot and 8-foot fluorescent lamps are available. They produce more light for the electricity consumed and enable better light control in new fixtures. Manufacturers generally offer better color rendition only in efficient lamps because their smaller tube diameter minimizes the use of expensive phosphor coatings.

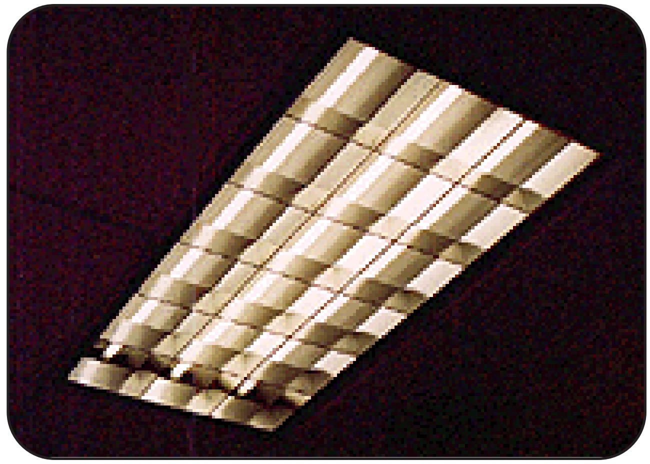
Action Moment

Renovating, moving to, or leasing an interior space usually offers the opportunity and need to revisit lighting. Changing the location of workspaces, adding or moving interior partitions, replacing ceilings, painting walls, or wallpapering all change the effectiveness of existing lighting. Where existing space includes defined task areas, yet a uniform lighting grid illuminates the area, substantial savings are possible. When specifying a new space, require lighting to be efficient.

Technical Information

1 **Fluorescent lighting is the best source** for most Federal lighting applications because it is efficient and can be easily switched and controlled. Modern fluorescent lamps have good color rendering and are available in many styles. Lamps are classified by (1) length, (2) form (straight or folded), (3) wattage, (4) pin configuration, (5) electrical type (rapid- or instant-start), and (6) phosphor type. When specifying a lighting system make sure that the lamp and ballast are electrically matched and the lamp and fixture optically matched.

2 **T-8, T-l0 and T-12 fluorescent lamps** have diameters of 1", 1-1/4" and 1-1/2" (the T-x gives the diameter in 1/8's of an inch) and are (usually) straight. They are most often used in 2x4, 1x4 and 8 foot fixture types. T-5 lamps are 5/8" diameter and are always folded. Folded lamps are good for smaller square fixtures (lxls or 2x2s). Refer to the table which illustrates the advantage of T-8s.



New fluorescent lighting fixtures that incorporate T-8 lamps, electronic ballasts, and good reflectors are key to better lighting at lower cost.

Comparison of 4-foot, fluorescent lamps

Lamp Type	T-12	T-10	T-8	T-12ES
Watts	40	40	32	34
Lumens	3200	3550	3050	2850

3 **When selecting a fixture,** make sure the fixture type is matched to the tasks being performed. Reflectorized industrial fixtures are very efficient and good for production and assembly areas but inappropriate for office applications. Lensed fluorescent fixtures ("prismatic lens" style) produce too much reflected glare off computer screens to be a good choice for today's electronic office. Instead, use parabolic louver fixtures that restrict light above 55˚ (0˚ is straight down), or use direct/indirect pendant-mounted fluorescent fixtures if high quality lighting is desired.

4 **After the fixture type has been identified,** make sure that it is efficient. The new Luminaire Efficiency Rating (LER) used by some fluorescent fixture manufacturers makes this comparison easier. Since LER includes the effect of the lamp and ballast type as well as the optical properties of the

Luminaire Efficiency Rating = (Fixture efficiency,% x Lamp lumens x # of lamps x Ballast factor) / Input watts fixture, it is a better indicator of the overall energy efficiency than simple fixture efficiency. An LER of 60 is good for a modern electronically-ballasted T-8 fluorescent fixture; 75 is very good and close to “state-of-the-art.”

5 **Where possible and permitted** by code, install dual level lighting (tandem or split-wiring) so that a 50% lighting level can be obtained when desired. This provides the occupant increased lighting flexibility and may save energy compared to an on-off only system.

6 **Where 4-lamp T-12 fixtures provide** adequate lighting, a good retrofit may be to replace the T-12s with half the number of T-10 lamps. Remove all four lamps, disconnect power to the inner ballast, and install two T-10s at the outside lamp positions. Using the outer lamp positions places the lamps further from the ballast heat and normally provides good light distribution. However, if light is blocked by the fixture itself, then the inner lamp position should be used.

The use of retrofit reflectors that fit into existing fixtures should be generally avoided. Except for one- and two-lamp industrial strips, fixtures already have reflectors consisting of the painted white surfaces inside the fixture. Because highly-reflective specular reflectors often produce striated patterns on the surfaces being lit and cause light to “dump” beneath the fixture, they can produce worse lighting than the original diffuse reflectors. Given the high cost of retrofit reflectors, it is often better to purchase new fixtures. An exception is where fixture replacement is not practical due to ceiling disruption—reflectors specially designed for the particular trough and application may be used.

Avoid inappropriate retrofits. If original lighting conditions are poor and cause visual discomfort or poor light utilization due to poorly placed fixtures, then conversion to T-10s alone will not help. While energy usage and electrical demand may be reduced, complete lighting redesign, retrofit, and even complete ceiling replacement to accommodating re-fixturing may be justified. Any retrofit should include a lighting design analysis.

New lighting design and re-fixturing with T-8 technology should be considered in any office renovation. It may be a better midterm choice than a T-10 retrofit.

Always transport and store fluorescent lamps horizontally to prevent phosphorous coatings from settling to the ends of the tubes.

Above 12 feet, high intensity discharge (HID) fixtures are usually a better choice. Fluorescent lighting is a good choice for general lighting for work areas, multipurpose rooms, bathrooms, offices, storage areas, and drafting areas.

Be sure to recycle all fluorescent lamps. Phosphor coatings contain harmful materials that should be eliminated from landfills. Waste recycling firms recover lamp material for industrial reuse.

Fort Lewis Army Base is undergoing extensive lighting renovations involving fixture replacement with T-8 lamps, electronic ballasts, dimmer controls, daylighting controls, and occupancy sensors.

References

Lighting guide specifications for lamps, ballasts, luminaires and reflectors have been developed under the FEMP Federal Relighting Initiative. Software to assist in system selection and design also is available from the FEMP Help Desk at (800) DOE-EREC, or from the FEMP Home Page at http:// www.eren.doe.gov/femp.

The *Lighting Upgrade Manual* may be downloaded at http://www.epa.gov/docs/CGDOAR/gcd_pubs.html#glpubs.

Environmental Protection Agency, Office of Air and Radiation, *Lighting Waste Disposal*, (6202J), 1994.

Western Area Power Association, *Electric Utility Guide to Marketing Efficient Lighting*, Golden, CO, 1990. (303) 231-7504

Contacts

EPA Green Lights and Energy Star Programs Hotline at (202) 775-6650.

Electronic ballasts (sometimes called solid-state) are efficient replacements for standard magnetic ballasts. Since the lamp and ballast form a system, the lamp is generally changed along with the ballast. Used with the right fluorescent lamp, electronic ballasts produce energy-efficient lighting while eliminating the flicker, hum and poor color rendition associated with conventional fluorescent lighting. Electronic ballasts capable of driving up to four lamps are available. These will continue to drive three lamps even after one has failed. For added cost, some electronic ballasts can also be dimmed, although this generally requires an additional low voltage control circuit.

Action Moment

Investing in new fixtures with electronic ballasts should be considered if the existing lighting system: is old and prone to failure; is inappropriate for current and future use; operates many hours daily; produces flicker, glare, or other discomfort to occupants; causes problems with sensitive electronics in the facility; or produces lighting levels that are too low or too high. Entire areas are commonly re-fixtured to save on installation costs and to allow implementation of integrated design, however, ballasts can be replaced in existing fixtures.

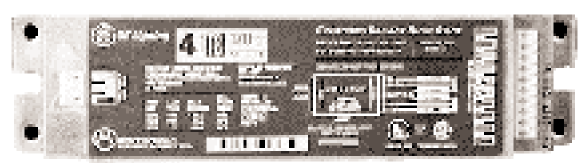
Technical Information

1 **Ballast specifications include:**

- Input voltage (usually 277 or 120 VAC)
- Number and type of lamps
- Power factor
- Total harmonic distortion (THD)
- Circuit type (instant-start or rapid-start, series or parallel operation)
- Ballast factor (BF)
- Ballast efficacy factor
- Minimum starting temperature

Good guidance for specifying these parameters is given in the Master Specifications Version 2.03 or Advanced Lighting Guidelines.

2 **“Instant-start” electronic ballasts** operate T-8 lamps in instant start mode. This mode of operation is slightly more efficient than rapid-start operation but comes with some degradation in lamp life (instant- start operation generally reduces 1amp life by about 25% using 15,000 hours rather than 20,000 hours). Rapid start operation is required for “reduced-output” ballasts (which have BF-70%) and for dimming applications. Parallel operation is generally preferable to series operation. If one lamp fails with a parallel circuit ballast, the other lamp(s) will continue operate. With series operation, neither lamp will operate if one fails.



Electronic ballast with "poke-in" connections for fast retrofitting.

3 **Dimming is available as an option** for some electronic ballasts. These are always of the rapid start, type and the dimming ballast will have two extra wires for a low voltage control signal (typically 0-10 VDC). By connecting a simple wall-mounted potentiometer to the low-voltage control wiring, an occupant can “dial-up” light levels between approximately 20% and 100% of maximum light output. Alternatively, the control wires can be connected to a ceiling-mounted photocell which will adjust the electric light level to supplement available daylight, thus saving energy (see Lighting Quality section 7.2).

4 **Power factor** indicates how effectively the input power and current are converted into usable watts of power delivered to the ballast. High-power-factor ballasts reduce current loads on building wiring and transformers. Specify power factors of 0.90 or higher for ballasts that drive large fluorescent lamps

5 **Ballast factor (BF)** or **relative light output** quantifies the light-producing ability of fluorescent lamps from a commercially available ballast compared to a laboratory reference ballast. Specify ballasts with a ballast factor or relative light output of between 85% and 100% to maximize light output from a specific lamp/ballast combination without over-driving the lamps. Over-driving lamps can shorten lamp life. A ballast may have one ballast factor for standard lamps and another for energy efficient lamps.

6 **Ballast efficacy factor** is the ratio between light output (lumens) of lamps operating on a ballast compared with input watts to the ballast. Ballast efficacy factor is useful in comparing ballasts within a type of lighting system, for example for the class of 4-foot fluorescent lamps.

7 **Total harmonic distortion** (THD) defines the effect a device has on the ideal electrical sinusoidal waveform. Harmonics within a facility can cause problems with electronic and communications equipment, overload transformers, and cause unexpected loading of the neutral in a three-phase system. Although other equipment can be responsible for harmonic distortion, ballasts are often blamed for these power quality problems. To avoid problems, specify ballasts with a THD of 20% or less. Ballasts with a THD of 5% or less are available for areas with sensitive electronic equipment or other special needs.

Many ballasts have a minimum starting temperature rating of 10˚C (50˚F), and may not be suitable for unconditioned locations. Other ballasts offer low-temperature starting down to -17˚C (0˚F).

One way to significantly reduce energy costs in overlit spaces is to replace existing magnetic ballasts with "reduced output" T-8 electronic ballasts (ballast factor around 70%) and re-lamp with T-8 lamps. Although the T-8 lamp output will be reduced 30% from the rated value, the new levels will be more appropriate and more energy is saved than using "normal" BF ballasts.

To avoid a significant reduction in ballast life, promptly replace fluorescent lamps that strobe or have blackened ends.

Unless there is a reason to do otherwise, specify electronic ballasts with the following performance:

- Ballast factor: 85% to 100%
- Power Factor: greater than 90%
- THD: 20% to 33%

Ballasts capable of operating four lamps can be wired to lamps in several fixtures, saving both initial equipment costs and operating costs.

Ballasts manufactured prior to 1979 may contain polychlorinated biphenyls (PCBs). PCBs are hazardous because they cause cancer, do not readily breakdown in the environment, and accumulate in plants and animals. PCB-containing ballasts must be sent to chemical waste landfills or high-temperature incinerators, or be recycled. Ballast recycling firms salvage reusable metals, reducing the volume of PCB-containing material for disposal.

References

Environmental Protection Agency, Office of Air and Radiation, *Lighting Waste Disposal*, (EPA 420-R-94-004) 1994.

Defense Logistics Agency, *Energy Efficient Lighting Catalog*, 1996. A good source of equipment information.

BC Hydro, *Design Smart: Energy-Efficient Architectural Design Strategies*, Burnaby, BC, Canada, 1995. (604) 540-8883

Contacts

FEMP’s ballast specifications are available from the FEMP Help Desk at (800) DOE-EREC.

EPA Green Lights Customer Service Center has information about ballast disposal. (202) 775-6650

Defense Logistics Agency, Defense Supply Center, Richmond, VA (800) DLA-BULB, or at http://www.dgsc.dla.mil

Lighting can be controlled automatically by many methods to save energy and lamp replacement costs: energy management and control systems (EMCSs, see section 3.8); daylight sensors that detect available daylight and control fixture outputs accordingly (section 7.2); photocells for exterior use, time-clocks and spring-wound timers (section 3.8); and occupancy sensors which prevent energy waste by turning off lights operating in unoccupied spaces, or by dimming lights according to daylight level within the building. This section covers occupancy sensors.

Action Moment

Installing occupancy sensors is relatively easy, requiring no particular timing for implementation. Facility managers should certainly consider enhanced controls when renovating, constructing new areas, or doing other electrical work. Good candidates for sensors include private offices, restrooms, hallways, lounges, computer rooms, clerical areas, conference rooms, warehouse aisles, storage rooms, copier rooms, classrooms, and loading docks.

Technical information

Occupancy sensors are triggered by infrared detection, ultrasonic emissions, microwaves, or sound. The first two technologies are the most popular, and hybrid infrared/ultrasonic sensors are available to combine the best features of both types. Sensors are either wall-mounted at the switch location or ceiling-mounted with remote control modules and relays.

1 **Infrared sensors** respond to movement of a heat source, such as a person moving in front of its field of view. Small motions, such as typing, may not trigger infrared sensors. These are suitable where there are no obstructions and they are not to be triggered by inanimate moving objects, such as a mobile twisting in an unoccupied classroom.

2 **Ultrasonic sensors** emit high-frequency energy in the 25 to 40 kilohertz range, well above normal human hearing. Objects moving in the space, even outside the direct line of sight, cause a frequency shift in the returning signal. Ultrasonic detectors are very sensitive to small movements, and may be triggered by wind-blown curtains or papers. These are suitable where obstructions such as bathroom partitions are present.

3 **Wall-mounted units** are designed to replace standard wall switches, and are so easy to retrofit that facility managers may choose to use them at any time. The best applications are small rooms, such as private offices, bathrooms, copy rooms, and storage closets.

4 **Ceiling mounted systems** usually control several lighting banks through infrared/ultrasonic occupancy sensors, a remote low-voltage controller, and line-voltage relays.

5 **Coverage area of sensors** depends on the room arrangement, room geometry, presence of partitions, location of sensors, the sensor's sensitivity setting, the type of sensor, and type of motion. Manufacturers' ratings are very rough guidelines. Facility managers should plan to adjust the sensor's sensitivity for specific applications.

Sensors vary widely in their ability to detect a person entering a room and maintain detection of small movements. This is true even within type groupings (ceiling-mounted infrared sensors, wall-mounted ultrasonic sensors). Be sure to consult comparative test reports.

"Automatic-off/manual-on" sensors allow occupants to decide whether lights are turned on, but they always ensure that lights are turned off after occupants leave. This type of sensor can be useful in areas such as break rooms, where quick visits to vending machines do not require lights to be turned on. For extended breaks occupants may want the lights on.

Lamp lumen depreciation sensors are designed to dim a lamp more when it is new and its light output is naturally highest. Light output is normally less at the end of lamp life, and the sensors accommodate by dimming less, or not at all. In this way, lighting designs that are normally overlit at beginning of lamp life and properly lit at end-of-life can save energy in the early years after relamping.

Occupancy sensors guard against custodial staff leaving lights on in unoccupied areas during and after nightly cleanings.

The Electric Power Research Institute estimates that occupancy controls save energy:

Private offices	25%
Open offices	18%
Conference rooms	35%
Restrooms	40%
Hotel Meeting Rooms	65%

Shortened lamp and ballast life may result from using occupancy sensors to control equipment that will turn on and off frequently. Ensure that the sensors are designed and calibrated to the situation.

Occupancy sensors can save 30% to 50% of the energy used for lighting, which comprises a major portion of typical electrical usage in facilities. The reduction in greenhouse gases from reductions in electrical generation needs depends on the individual occupancy sensor installation.

User satisfaction is important, and land users need orientation for a successful outcome. Dissatisfied occupants may sabotage the controls, and negate the savings.

Alcoa Composites in Monrovia, CA enjoys $26,000 annual electricity savings as a result of installing ultrasonic sensors in offices, work areas, and hallways. The installation paid for itself within 1 year.

Contacts

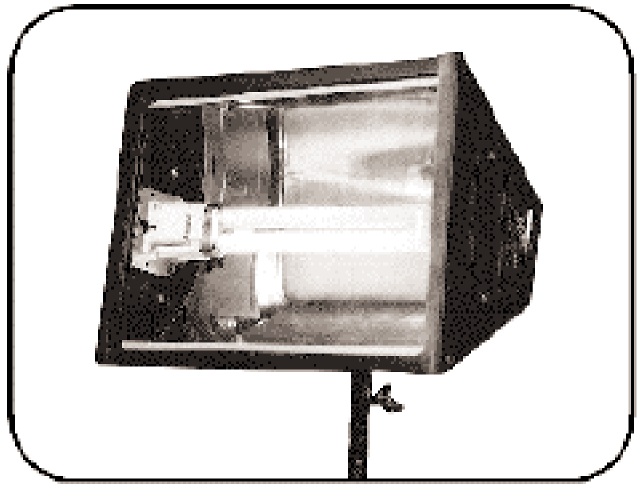
Renssellaer Polytechnic Institute, Lighting Research Center, National Lighting Product Information Program (NLPIP), Troy, NY, offers comparative test reports for purchase. (518) 276-8716 or http://www.lrc.rpi.edu/

Environmental Protection Agency, Green Lights Program at (202) 775-6650 offers general information.

Exterior lighting is used to improve security, enhance safety, and to direct pedestrians and vehicles. It is also used in nighttime work areas, sports facilities, landscapes and cityscapes. A wide selection of new lamps, ballasts, fixtures and controls are available to lighting designers to replace inefficient exterior lighting systems.

Action Moment

Exterior lighting systems using incandescent, fluorescent, or mercury vapor lamps should be evaluated, redesigned, and replaced with new hardware using compact fluorescent, metal halide, or sodium lamps.



Compact fluorescent floodlights provide high quality light with very low energy.

Technical Information

Exterior lighting principles should be considered when implementing any exterior lighting retrofit. These principles assist in achieving energy conservation and also provide superior lighting quality to users.

1 **Minimize glare**. Glare greatly detracts from nighttime visibility. If two parking lots are equally illuminated to 5 footcandles, the installation with the least glare from the fixtures will provide the greatest visibility, safety, and visual comfort. Unfortunately, numerical levels for glare are not included in exterior lighting standards.

2 **Minimize or eliminate light directed upward**. Light emitted at angles of 80^{o} or higher (straight down is 0^{o}) fails to produce useful illumination on horizontal surfaces in open areas such as parking lots. At these high angles light produces significant glare, light pollution, and energy waste. Light above 90^{o} is totally wasted and produces undesirable sky glow.

3 **Direct light only where it is needed**. New fixtures allow designers to control where light falls. By eliminating light spillage into surrounding areas, lower wattage lamps can be used. "Barn lights" that contain 175-watt mercury vapor lamps are good examples of fixtures that should be avoided.

4 **Avoid over-lighting**. A good rule of thumb is that, "a little light is a lot of light where there isn't any other light."

5 **Consider human usage patterns**. For example, a driver traveling in rural areas will temporarily be blinded by suddenly encountering bright roadway lights. In driveways, place the first few lights at lower levels to counter this problem.

6 **Turn off lights by 11:00 P.M.** unless they are needed for security or safety.

7 **Design systems to accommodate maintenance accessibility;** to have long ballast and lamp lives; and to resist dirt, animal droppings, bird nests, vandalism, and water damage.

Some high intensity discharge (HID) ballasts incorporate control circuits that allow easy attachment of motion sensors or energy management system controls.

Use HID lamps with specific orientations rather than universal position lamps. Lamps that specify burning in the horizontal, base-up, or base-down positions can produce 10% to 20% more light and last up to 60% longer.

Consider photovoltaic (PV) lighting for remotely located sites not presently served by power lines. Locations requiring low levels of light that are as close as 50 ft. from a power source can be good applications for PV lighting. Examples are signs and bus shelter lights (See section 3.10.1).

Low-pressure sodium lights are the most efficient light source, but are generally more difficult to control. The monochromatic yellow light they produce has absolutely no color rendering capability. Three cars—red, blue and black—may all appear identical under these lights. However, if astronomical observatories are nearby, using low-pressure sodium (LPS) will help reduce light pollution because filters for specific wavelengths can be installed on telescopes.

Relamp groups of fixtures at the same time to reduce maintenance costs, lamp stocking, and light depreciation toward the end of lamp life.

Control of exterior lighting may be provided by manual switches, time clocks, photocells, motion sensors, or energy management and control systems. By automating controls, users need not manually switch lights on and off each night. However, where time clocks are used, they should be periodically checked to ensure the time is set correctly and adjusted for changes in time of sunrise and sunset. Where photocells are used, they should be very sensitive to low light levels and placed in open areas, such as on roofs. This will help ensure that lights do not operate unnecessarily at dusk and dawn. See section 3.8 for more information about control systems.

References

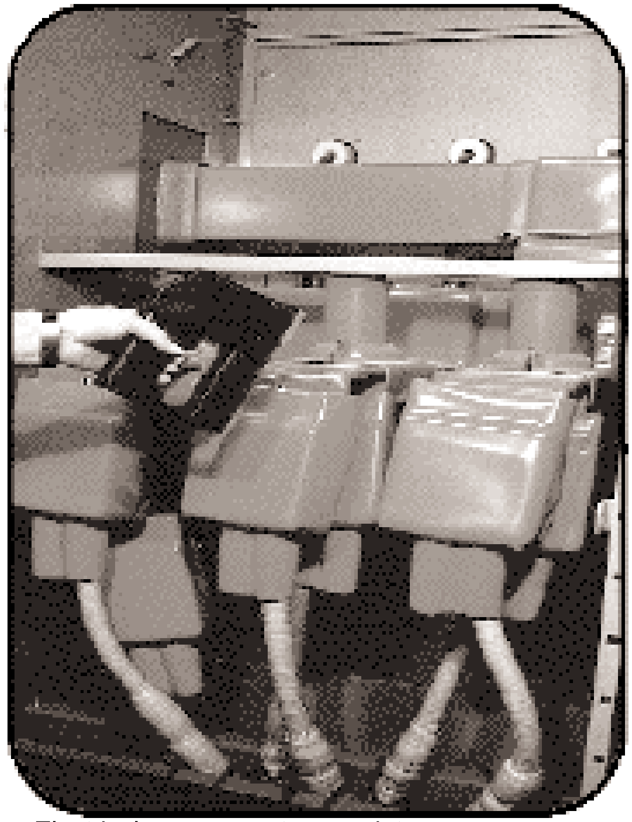
Illuminating Engineering Society of North America, *IES Lighting Handbook*, eighth edition, New York, NY, 1993.

Markowitz, Gary, "HID Luminaries: An Overview," *Architectural Lighting*, Oct/Nov 1993.

Contacts

International Dark-Sky Association, 3545 N. Stewart Ave., Tuscon, AZ 85716 or at http://www.darksky. org/ offers information on techniques for providing good outdoor lighting without contributing unnecessarily to light pollution.

Electricity is the largest energy source in most facilities. Electric utility bills include both energy charges in kilowatt-hours and power demand charges in kilowatts. Rates may vary by season and time of day. Utilities penalize facilities with low power factors that require the utility to provide power-factor compensations. In the broadest sense, power systems include HVAC equipment, motors, lighting, kitchen appliances, water heaters, and plugloads that deliver power to end-users. The focus of this Section is on distribution components such as transformers, switchgear, wiring, and other power system components. Analysis of power systems is discussed in section 3.5.1 and transformers are addressed in section 3.5.2.



Electrical power system maintenance programs will increase both efficiency and reliability.

Action Moment

Consider efficiency, reliability and maintenance of power systems whenever installing, renovating, or replacing equipment. Electrical power systems are often thought to be stable, reliable, and to have little potential for saving energy. However, there are opportunities within the facility's distribution system to save energy, increase equipment life, and reduce unscheduled outages.

Technical Information

Opportunities for improving efficiencies of electrical power systems include evaluating and correcting voltage imbalances, voltage deviations, poor connections, undersized conductors, poor power factors, insulation leakage, and harmonics. Components to check in a maintenance program include transformers, conductors, switchgear, distribution panels, and connections at loads and elsewhere.

Voltage imbalances are problematic differences between relative voltage levels among the three phases in part or all of a facility. Voltage imbalances result in preventable energy waste, excessive equipment wear, and premature equipment failure. Power demands on all three power phases should be virtually equal in order to maintain equal voltages in all phases. Problems with conductors, connections, and transformer settings may cause imbalances in any facility. However, supplying single-phase needs while maintaining three-phase balance is a challenge.

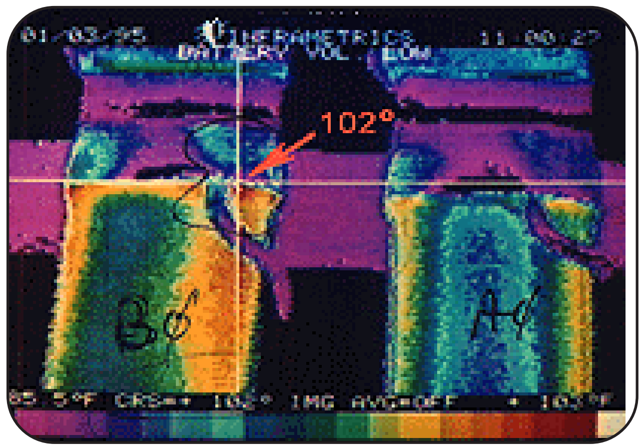
Before making any major changes to the distribution system, consider the effects on the phase-to-phase balance.

Avoid imbalance in supply circuits by distributing single-phase loads such as lighting, single-phase motors, resistance heating, and plugloads among phases.

Maintenance Type	Philosophy
Reactive maintenance	Repairs are made or components are replaced only upon failure.
Preventive maintenance	Includes inspecting, diagnosing, and servicing electrical systems to minimize future equipment problems or failures.
Predictive maintenance	Uses tests to predict the necessary service interval and targets equipment with the greatest service needs.
Proactive maintenance	Employs failure analysis and predictive analysis as feedback to improve maintenance practices.

The annual cost penalty for operating a 100 hp motor with a 4% voltage imbalance is approximately $830 per year. This cost is due to reduced motor life, energy charges, and electrical demand charges. This assumes continuous operation, utility rates of $0.04 per kWh, and demand charges of $4.00 per kW.

Match the maintenance sophistication of electrical facilities to the situation and resources. The more critical the equipment, the more maintenance resources should be devoted to it. Maintenance programs for electrical distribution systems may be reactive, preventive, predictive, or proactive. The table on the next page shows the distinguishing features of differing maintenance strategies. With good record-keeping, a manager can develop the tools needed for at least a predictive maintenance program.



The hot spot on this infrared scan shows a problem with a control wire connection in a large generator breaker.

References

Washington State Energy Office, *Keeping the Spark in Your Electrical System: An Industrial Electrical Distribution Maintenance Guidebook*, (WSEO 93-15), Olympia, WA, 1995.

An analysis of an electrical power system may uncover energy waste, fire hazards, and impending equipment failure. A well-executed analysis takes planning and lays the foundation for ongoing reliability-based maintenance.

Action Moment

The best time to initiate preventive maintenance on electrical systems is before failures occur. Problems may be hidden until failure occurs, especially if the system is not regularly maintained. In a new facility, maintenance should begin from the outset. For electrical systems, it is never too late to start a regular maintenance program.

Infrared thermography can quickly identify electrical power system problems and should be included in a proactive maintenance program.

Technical Information

"Tune-ups" for electrical power systems yield both direct and indirect efficiency improvements and increase the reliability of equipment. Direct improvements result from correcting leaks to ground and cutting resistive (I^2R) losses in the distribution components. Indirect improvements result from improving efficiency of equipment previously operating with poor quality input power, such as three-phase motors operating with phase-to-phase voltage imbalances.

Establish a preventative maintenance program with good record keeping.

1 Document the system component and loads starting with the available drawings and other documentation. Update them to "as-built" and keep them current.

2 Inspect components noting discoloration, deformation, damage or hot odors, noise, or vibration.

3 Manually operate all switches and disconnects on a monthly schedule to help eliminate any corrosion.

4 Conduct a regime of electrical tests designed to identify actual and potential problems. This may include contact condition assessment with a voltage drop survey, infrared thermography, power factor assessment, or voltage assessment to determine imbalances and deviations from target voltages.

5 Consider a proactive maintenance program with the predictive elements discussed in Section 3.5.

When conducting electrical assessments, be aware of varying conditions. Power quality may change greatly at night or other times because of changes in loads.

Facility managers increasingly find that reliability-centered maintenance can save money, energy, and downtime. A lumber/plywood facility in Oregon projected $125,000 in potential savings by instituting an electrical system preventive maintenance program. Estimating true savings is difficult due to the uncertainty about when failures will occur, what equipment will be damaged, and how long problems will last.

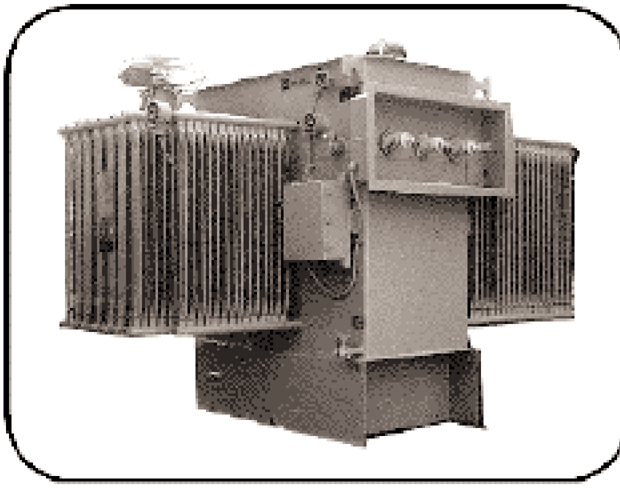
System Problem	Common Causes	Possible Effects	Solutions
Voltage imbalances or differences between relative voltage levels among the three phases in all or part of a facility.	Improper transformer tap settings, one single-phase transformer on a polyphase system, single-phase loads not balanced among phases, poor connections, bad conductors, transformer grounds or faults.	Motor vibration, premature motor failure, energy waste. A 5% imbalance causes a 40% increase in motor losses.	Balance loads among phases
Voltage deviations refer to voltages being too low or high.	Improper transformer settings, incorrect selection of motors, e.g., a 230/208 motor (which is actually 230 rated) on a 208 circuit.	Over-voltages in motors reduce efficiency, power factor, and equipment life, and increase temperature.	Check and correct transformer settings, motor ratings and motor input voltages.
Poor connections may be in distribution or at connected loads.	Loose bus bar connections, loose cable connections, corroded connections, poor crimps, loose or worn contactors, corrosion or dirt in disconnects.	Wastes energy, produces heat, causes failure at connection site, leads to voltage drops and voltage imbalances.	Use IR camera to locate hot-spots and correct.
Undersized conductors.	Facilities expanding beyond original designs, poor power factors.	Voltage drop and energy waste.	Reduce the load by conservation insulators.
Insulation leakage.	Degradation over time due to extreme temperatures, abrasion, moisture, chemicals, conductor insulation inappropriate for conditions.	May not cause breaker to trip, and may leak to ground or to another phase. Variable energy waste.	Replace conductors, insulators.
Low Power Factor	Inductive loads such as motors, transformers, and lighting ballasts; non-linear loads, such as most electronic loads.	Reduces current-carrying capacity of wiring voltage regulation effectiveness, and equipment life. May increase utility costs.	Add capacitors to counteract reactive loads.
Harmonics (non-sinusoidal voltage and/or current wave forms)	Office electronics, telephone PBXs, uninterruptable power supplies, variable frequency drives, high` intensity discharge lighting, and electronic and core-coil ballasts.	Over-heating of neutral conductors, motors, transformers, switch gear. Voltage drop, low power factors, reduced capacity.	Take care with equipment selection and isolate sensitive electronics from noisy circuits.

References

IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems, (ANSI/IEEE Standard 242-1986), Institute of Electrical and Electronics Engineers, 1986.

Washington State Energy Office, *Keeping the Spark in Your Electrical System: An Industrial Electrical Distribution Maintenance Guidebook*, (WSEO 93-15), Olympia, WA, 1995.

Customer-owned transformers allow facilities to purchase power at lower costs and at high voltages, and then generate the range of voltages needed for internal applications. Transformers commonly used in large facilities are oil-filled, pole-mounted types for overhead distribution; and oil-filled, pad-mounted models for underground feeds. Dry-type transformers, used for smaller, special applications, are typically located inside buildings away from harsh environments. Transformer failure may be catastrophic and cause power interruptions. Other transformer problems are more subtle and may result in energy waste that goes unchecked for years.



Energy-efficient transformers should be specified when replacing or obtaining equipment.

Action Moment

Purchase energy-efficient transformers and practice good installation techniques whenever replacing or adding new equipment. Commence proactive transformer maintenance along with other electrical maintenance functions.

Technical Information

1 **Efficiencies of most dry-type transformers** range from 93% to 98% with core losses due to magnetizing and coil losses from impedance and resistance. When purchasing transformers, look for those with high efficiency ratings that fit the need. Be sure to obtain all transformer loss information from the manufacturer and match the transformer to the load profile. Manufacturers trade-off coil losses (most significant at full load) and core losses (most significant at low load). Consequently a low temperature rise unit that operates very efficiently at high load may be inefficient at low load.

Each year, according to insurance industry figures, there are more than 100 incidents of electrical and fire damage due to inadequate transformer maintenance, causing $10 million in losses.

2 **Disconnect the primary side of transformers not serving active loads.** Transformers consume power even when loads are switched off or disconnected. Disconnecting the primary side of transformers to save transformer standby losses is safe provided that critical equipment such as clocks, fire alarms, and heating control circuits are not affected.

For three-phase transformers, ensure that each phase balances in voltage with others to within the minimum transformer step. If this fails to yield equal tap settings, redistribution of loads is necessary.

3 **Reduce acoustical noise** from pad-mounted transformers by proper design. In areas where personnel would be affected by the 60 Hz hum of power transformers, use isolators to reduce transmission to the building's structural components. Install isolators between the transformer core and housing, and also between the housing and the building structure.

O/M **Visually inspect transformers** to verify that oil is contained and that connections appear to be sound.

Scan temperatures of transformers using infrared thermography to determine points of energy waste and pending failure. Criteria for assessment include ambient air temperature, rated-rise of similar transformers under the same conditions, and an absolute maximum allowable temperature.

Maintain balanced voltage with polyphase transformers by maintaining equal tap settings. Balance single-phase loads among phases to keep voltages within 1% of the average.

Be careful when connecting single-phase transformers to a three-phase system. If the load is large, a three-phase transformer should be used and the single-phase loads should be balanced.

Cooling oil in old transformers may contain polychlorinated biphenyls (PCBs). PCBs are hazardous, cancer-causing agents that must not be released into the environment. When replacing PCB-containing transformers take care to avoid spillage. Collect oils for recycling, incinerate at high temperature, or landfill in a secure, authorized area. Follow applicable safety and environmental protection standards for handling and disposal.

References

Knisley, Joseph R., "Controlling Building Noise with Good Electrical Designs," *EC&M*, Sept 1995.

Oak Ridge National Laboratory, *The Feasibility of Replacing or Upgrading Utility Distribution Transformers During Routine Maintenance*, (NTIS Order Number DE95002372), Oct 1972.

Wahlstrom, Randy, "Choosing Energy Efficient Transformers," *Energy Engineering*, Vol 92, No 5, pp 6-17.

Washington State Energy Office, *Keeping the Spark in Your Electrical System: An Industrial Electrical Distribution Maintenance Guidebook*, (WSEO 93-15), Olympia, WA, 1995.

There is a wide variety of energy-consuming devices in Federal buildings, some of which are only recently beginning to receive attention due to their power and water consumption. Office equipment, food service equipment, and laundry equipment have excellent potential for reducing energy consumption.

Office electronics are the most rapidly growing consumer of electrical power in commercial buildings.

Action Moment

When selecting office, food, or laundry equipment, the facility manager may reduce energy consumption by opting for the high efficiency, high performance equipment described in sections 3.6.1 and 3.6.2.

Technical Information

1 **Selecting energy-efficient equipment**—PCs, monitors, copiers, printers, and fax machines—and turning off machines when not in use can produce enormous energy savings. A typical PC operating 9 hours a day will use only 38% of the power consumed by a computer operating 24 hours. Power management devices on computers can reduce energy usage even further by turning down the power when the computer is unused. Copiers, laser printers, faxes, and other office equipment can save up to 66% of their 24-hour power consumption by keeping them on only during office hours.

2 **EPA's Energy Star program**, which began in 1992, was reinforced by a 1993 Executive Order that required all Federal agencies to purchase only Energy Star compliant computers. Computers in this program must have the capability of powering down to 30 watts after a user-controlled 15- to 30-minute delay.

3 **High-capacity, multistage dishwashing machines** are designed for medium to large food service operations, including hospitals, colleges, hotels, and restaurants. The multistage dishwashers reuse water from the two-rinse stages to pre-wash the dishes. In addition to water savings, these devices save considerable detergent and rinse additives. Due to the improved design of the dishwashers, dish breakage has been reduced.

4 **Prior to upgrading a kitchen, consider the following energy-efficient types of equipment:** infrared fryers; convection ovens (to include steamer models); microwave ovens; and specialized equipment, such as a pizza oven. Computerized controls can produce savings since they automatically time the cooking of certain foods. Energy-efficient exhaust hoods can provide significant savings because they use outside air rather than inside conditioned air for ventilation. Side curtains around cooking equipment help restrict the flow of conditioned air to the outside. Exhaust air can be used to pre-heat air for HVAC purposes or to pre-heat water.

5 **Microcomputers on newer model clothes washing machines** permit precise control of water temperature and cycles. Operate washers and dryers at full loads rather than partial loads in order to save energy.

6 **Laundry water temperatures should be reduced** to 71˚C (160^{o}F) unless prohibited by codes. Some soaps and detergents will perform at even lower temperatures, and their use is encouraged. Water temperatures should be checked, with an accurate thermometer, and adjusted as needed.

Contacts

The EPA Home Page at http://www.epa.gov/docs/GCDOAR/es_office.html has information about Energy Star office electronics.

Tiller, D.K. and G.R. Newsham, “Switch Off Your Office Equipment and Save Money,” *IEEE Industry Applications Magazine,* 2(4), 1996 pp. 17-24.

Office electronics are the fastest growing use of electricity in commercial buildings in the United States, with over 30 billion kWh of annual consumption valued at more than $2.1 billion. Users now have the option of installing energy-efficient office equipment that can potentially reduce the energy consumption of conventional equipment by 50%, at the same time reducing air conditioning loads, irritating noise from fans and transformers, and electromagnetic field emissions from monitors.

Action Moment

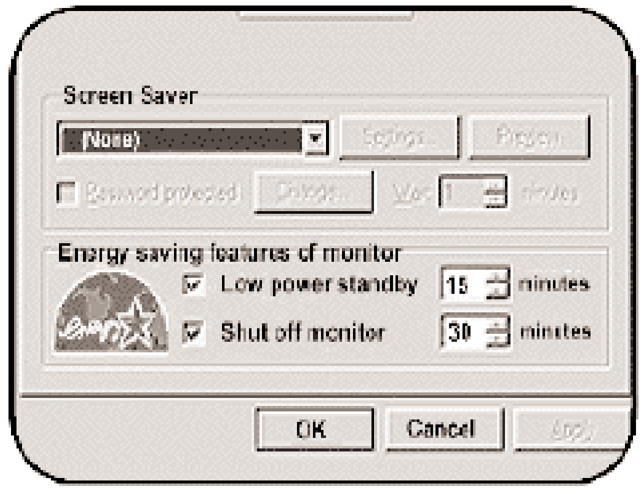
When new office equipment such as computers, monitors, copiers, or fax machines is purchased, be certain they are Energy Star-compliant as required by Executive Order 12845. DOE and EPA recently announced joint support for the Energy Star Programs.

Computers

To save energy used by computers, buy an Energy Star computer and Energy Star monitor, or a laptop. Laptops draw only 15 to 25 watts compared to the 150 watts used by a conventional, non-Energy Star PC/monitor. Buy monitors no larger than required. Energy Star computers save energy, provided the following requirements are met:

1 **The computer's energy management features must be activated**. Some computers are shipped in an activated state. Others require the user to enable the power management features.

2 **The computer and its network card must be compatible with the network**. The manufacturer must have tested it with the specific network type to which it is attached, or it may not work.



Energy Star monitors allow the user to set low power and power-off timing via software.

3 **The monitors must be capable of entering a low power state.** Monitors must be capable of being shut off by a Display Power Monitoring Signal (DPMS) signaling protocol, by a software utility, or by a special plug connected to the PC.

4 **"Universal" monitors** can both accept a DPMS from a PC, and run power management from a non-DPMS PC.

5 **The computer must be able to operate commercial software** both before and after recovery from a low power state. The manufacturer should supply information verifying this capability.

Turn computers off at night, on weekends, and during the day when they are not in use.

A 150-watt PC/monitor will cost $105 per year to operate if left on continually. Turning it off at night and on weekends will save $80 per year in energy costs. Turning it off when not in use during the day can save another $15 per year.

Printers/Facsimile Machines

1 **Rather than buying one printer per worker**, use a network or printer-sharing switch to allow laser printer sharing.

2 **To reduce printer use**, implement paper reduction strategies and use e-mail.

3 **Although older Energy Star printers required a delay time to return to print mode**, newer models return to operating mode immediately from low power mode.

4 **Fax machines now have Energy Star ratings** which, through their lower standby energy use, reduce power consumption by 50%.

5 **Use plain-paper fax machines to save money**. Also, thermal fax paper is not acceptable in typical paper recycling programs.

6 **Use e-mail or direct computer faxing** instead of paper-faxes whenever possible.

DOE-EPA's Energy Star Printer, Fax and Printer/Fax Combination Requirements.

Printer/Fax Speed (pages/minute, ppm)	Average Watts in Low Power Mode	Printer Default Time (min)	Fax Default Time (min)
0<ppm<7	15	15	5
7<ppm<14	30	30	5
ppm>14 and high end color	45	60	15

Copiers

1 **Copiers use more energy** than any other piece of office equipment. Be sure to buy an Energy Star copier and be sure it is sized correctly for the job.

2 **Again, use e-mail,** web sites, and "paperless faxing" where possible.

3 **Double-sided copying** is an important energy- and paper-saving feature. Try to use paper with a high recycled content.

4 **Copying in batches** significantly reduces energy consumption because the printer spends far less time in high-power mode.

DOE-EPA's Energy Star Photocopier Program (Tier 2) — Effective 1997

Copier Speed copies per minute (cpm)	Low Power Mode (watts)	Recovery TIme (30 seconds)	Off Mode (watts)	Off Mode Default Time	Automatic Duplex Mode
0<cpm<20	none	no	<5	<30 min	no
20<cpm<44	3.85 x cpm + 5	yes	<10	<60 min	optional
cmp>44	3.85 x cpm + 5	recommended	<15	<90 min	default

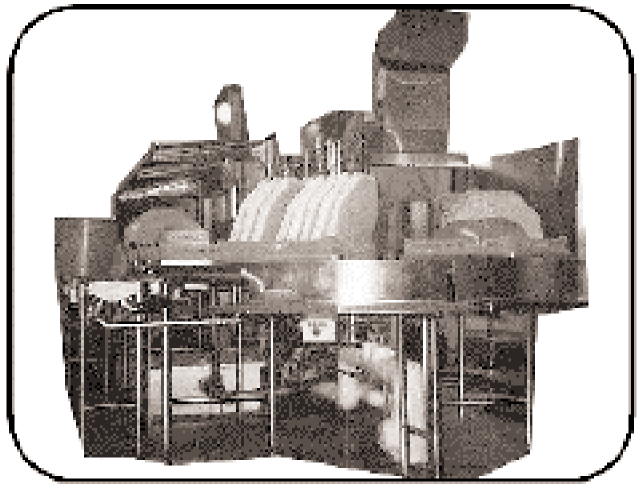
References

Tiller, D.K. and G.R. Newsham, "Switch Off Your Office Equipment and Save Money," *IEEE Industry Applications Magazine*, 2(4), 1996, pp 17-24.

Contacts

The EPA Home Page at http://www.epa.gov/docs/GCDOAR/es_office.html has information about Energy Star office electronics.

Food service and laundry equipment can be among the heaviest consumers of energy and water. New types of high-capacity, multistage dishwashing machines, high-efficiency refrigerators, and other equipment provide significant opportunities to save resources and money. In each case, heat recovery systems can be used to capture waste energy from appliances and use it to pre-heat air for HVAC purposes or to pre-heat water.



New commercial dishwashers reduce water, energy, and labor requirements

Action Moment

When replacing food service and laundry equipment, choose energy-efficient models and units that incorporate waste heat recovery.

Dishwashers

New high-capacity, multistage dishwashing machines are designed for medium to large food-service operations including hospitals, colleges, hotels, and restaurants. In addition to reducing water usage and load requirements, manpower requirements are reduced by 50%.

1 **Multistage dishwashers** reuse water from the two rinse stages to prewash dishes. In addition to water, these devices save considerable detergent and rinse additives. Due to their improved design, breakage is also significantly reduced.

2 **Some dishwasher models** are available with an optional power scraper that removes caked-on, dried food. This can be particularly useful when there is a significant time lag between use and washing.

3 **Typical throughput** of dishes in a high-capacity, multistage washing machine is 3,500 to 3,700 dishes per hour, with a conveyor speed of 5 to 6 feet per minute.

$ **A recent DOD cafeteria installation** of the new multistage dishwashing equipment cost $57,800. The result was a water reduction of 500,000 gallons per year, saving $2,000 per year. Manpower savings were $19,000 per year. The payback time for this installation was 2.7 years and it will save almost $500,000 over its 25-year projected life.

Refrigerators and Freezers

In commissaries, up to 50% of energy consumption can be due to refrigerators and freezers.

1 **Refrigerators and freezers** are divided into medium-temperature (MT) systems (down to 20˚F) and low- temperature (LT) systems (down to -25˚F).

2 **New equipment is available** with EERs of 7 to 9 for MT systems and 5 to 6 for LT systems. Replace old, inefficient systems with high-efficiency, new systems to obtain significant savings immediately.

Relying on refrigerator cases to cool the interior of a space is not very useful, as HVAC systems typically have EERs of 10 to 12 versus the 5 to 9 for refrigeration equipment. This translates to a difference of 40% in energy use. Air spillage from the refrigeration equipment to the space should be minimized.

Product literature is clearly very important to insure proper operation of refrigerators and freezers. Some of the causes of excessive energy use by these devices are: controls set too low; doors that do not close properly; and worn/torn gaskets. An accurate thermometer is needed to check existing temperature conditions. Cleaning condenser heat transfer surfaces to remove dirt and scale is very important for proper and efficient operation. Overloading the unit may result in over- or under-cooling the stored product.

Cooking Equipment

The key ways to save energy when using cooking equipment are: (1) turn equipment off when not in use; (2) use a temperature no higher than necessary; (3) match the equipment to the job; and (4) cook as efficiently as possible. This latter step includes adjusting flames on ranges to just touch the bottom of cookware, avoiding unnecessary oven door openings; cooking foods with the same requirements simultaneously, and cooking in volume.

When upgrading a kitchen, consider the following energy-efficient types of equipment: infrared fryers, convection ovens (including steamer models), microwave ovens, and specialized equipment. Specialized equipment, such as pizza ovens, are designed to cook specific foods very efficiently. Computerized controls can also produce savings, since they automatically time the cooking of certain foods.

Energy-efficient exhaust hoods can provide significant savings because they use outside air rather than inside conditioned air for ventilation. Side curtains around cooking equipment can help restrict the flow of conditioned air to the outside. Exhaust air also can be used to pre-heat air for HVAC purposes or to pre-heat water.

Laundry Equipment

Microcomputers on newer-model laundry equipment permit precise control of water temperature and cycles.

Using equipment efficiently means ensuring that washing machines and dryers are operated at full loads rather than partial loads.

Laundry water temperatures should be reduced to 160^{O}F, unless prohibited by code. Some soaps and detergents perform at lower temperatures and should be used where appropriate. Temperatures should be checked with an accurate thermometer and adjusted as needed.

To reduce energy use of clothes washers and dishwashers: repair leaks; insulate storage tanks and distribution piping; clean sediment out of equipment; and test/tune up water-heating components.

Horizontal-axis washing machines, very popular in Europe, are extremely energy and water efficient. Only recently have American manufacturers begun to produce this type of equipment. Investigate procuring this type of machine when in the market for clothes washing equipment.

References

American Council for an Energy Efficient Economy (ACEEE), *The Most Energy-Efficient Appliances —1996 Edition*, Washington, DC.